Advanced Propulsion Systems for Low-Cost Access to Space

Transformational Space Launch and Operations Technologies Conference

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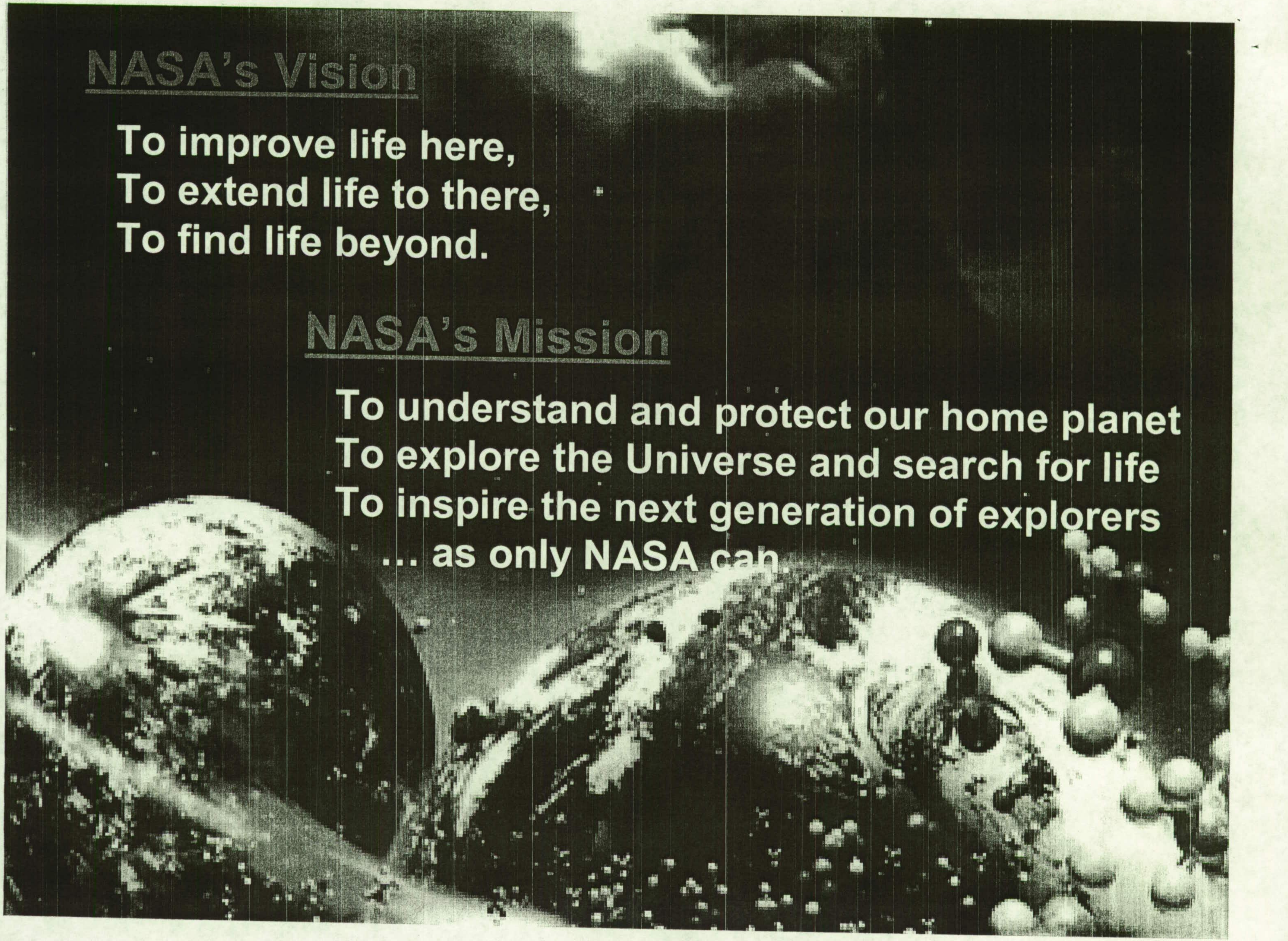
Outline

- NASA Access to Space Goals
- Rocket-Based Combined Cycle Engines
- Turbine-Based Combined Cycle Engines
- Pulse Detonation Engines
- Conclusions

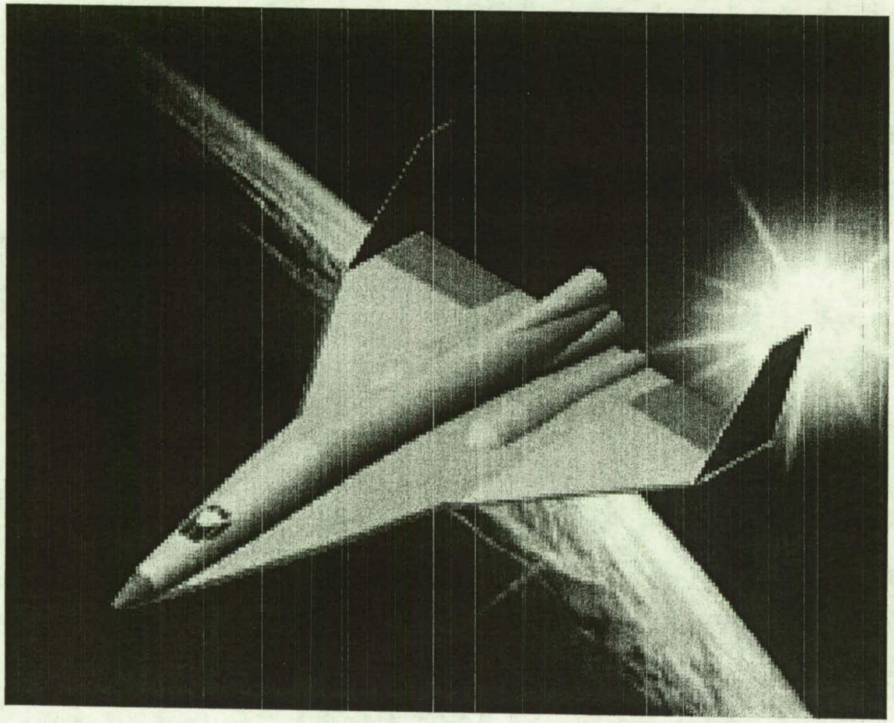

NASA's Vision
To improve life here,
To extend life to there,
To find life beyond.
NASA's Mission
To understand and protect our home planet
To explore the Universe and search for life
To inspire the next generation of explorers
... as only NASA can.

NASA's Space Access Goal

Ensure the provision of space access and improve it by increasing safety, reliability, and affordability.

- The launch phase continues to be the highest risk period of any space mission.
- Launch costs remain an obstacle to the complete utilization of space for research, exploration, and commercial purposes
- Improving the Nation's access to space through the application of new technology is one of NASA's primary roles.

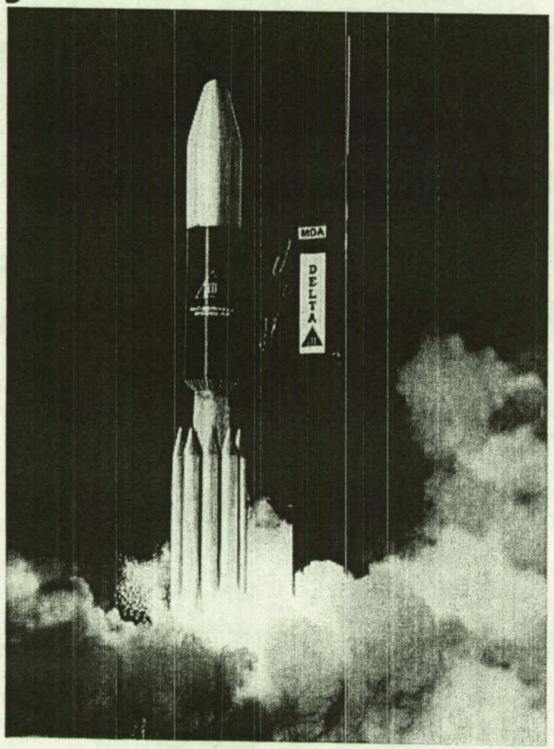
Access to Space Cost Goals

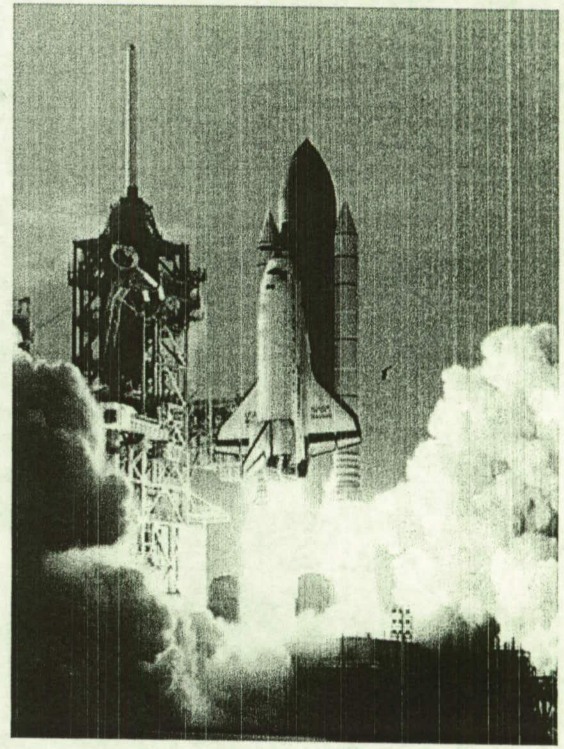


- Reduce Payload Cost from $10,000 to $1,000 per pound within 10 years
- Reduce Payload Cost from $1,000 to $100's per pound by 2025

Why is Space Access So Costly?

- Expendable components
- Expendable vehicles
- Vehicle re-assembly
- Refurbishment
- Supply and demand

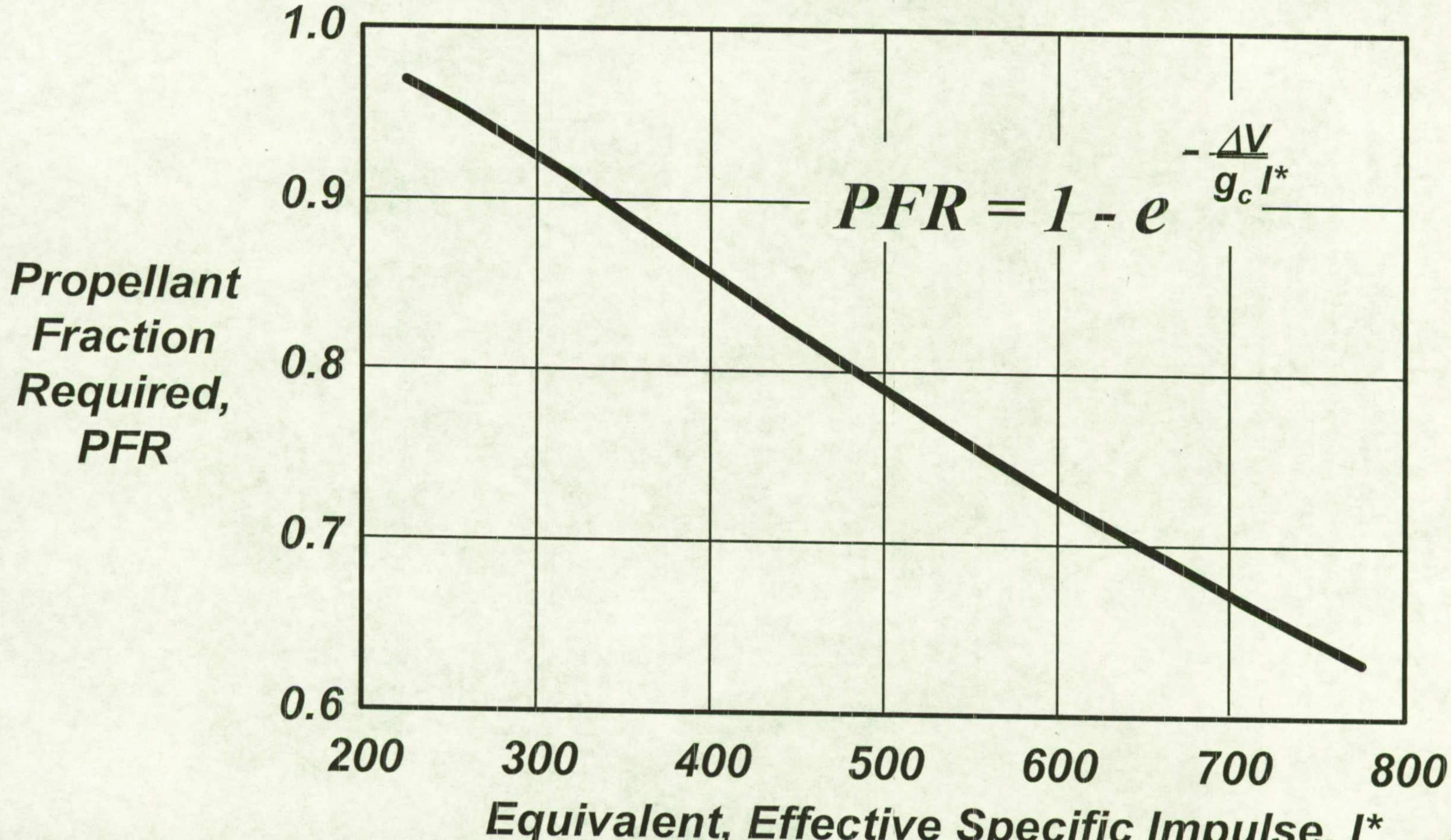




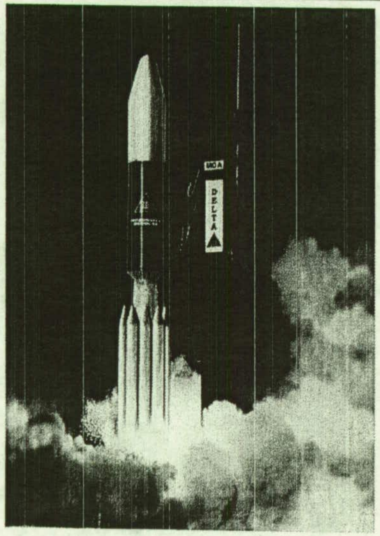
A highly-reusable, single-stage-to-orbit (SSTO) launch vehicle would dramatically reduce the cost of space access...

The "Rocket Equation" for SSTO

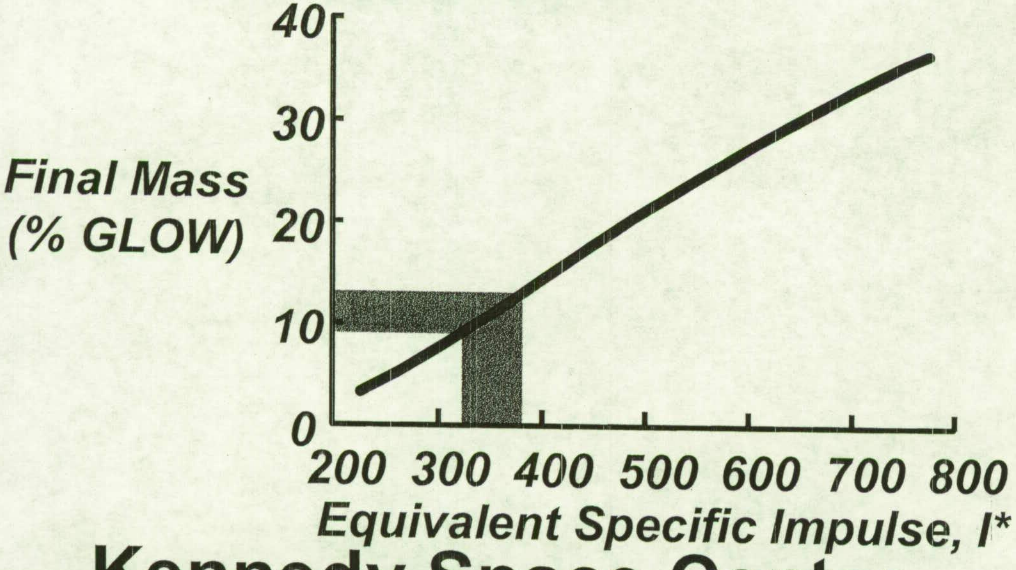
The amount of propellant required to achieve orbit is governed by Newton's second law...

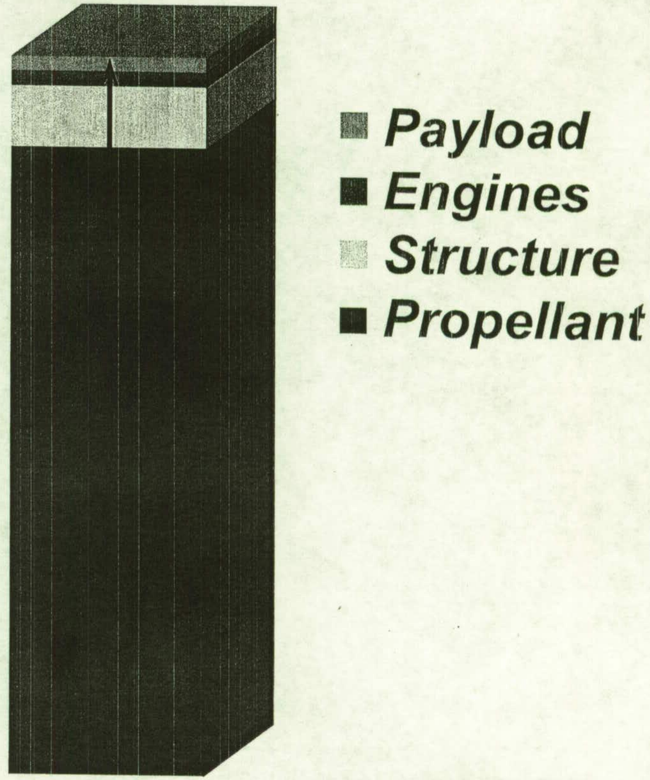


The Rocket I* "Barrier"

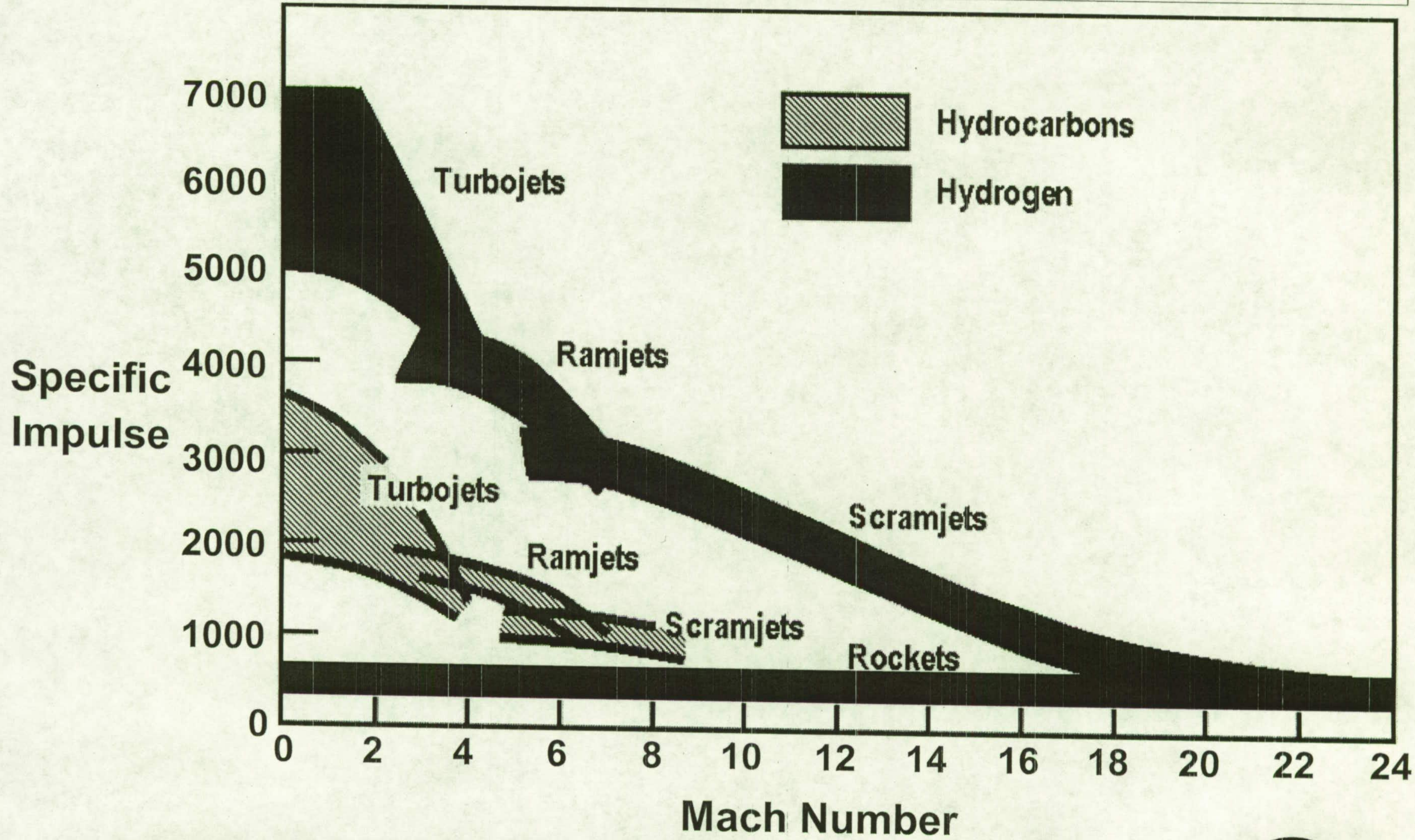


Rockets are limited to I* values below 400, leaving only 10-12% of the gross lift-off weight for reusable structure and engines





Propulsion System Performance



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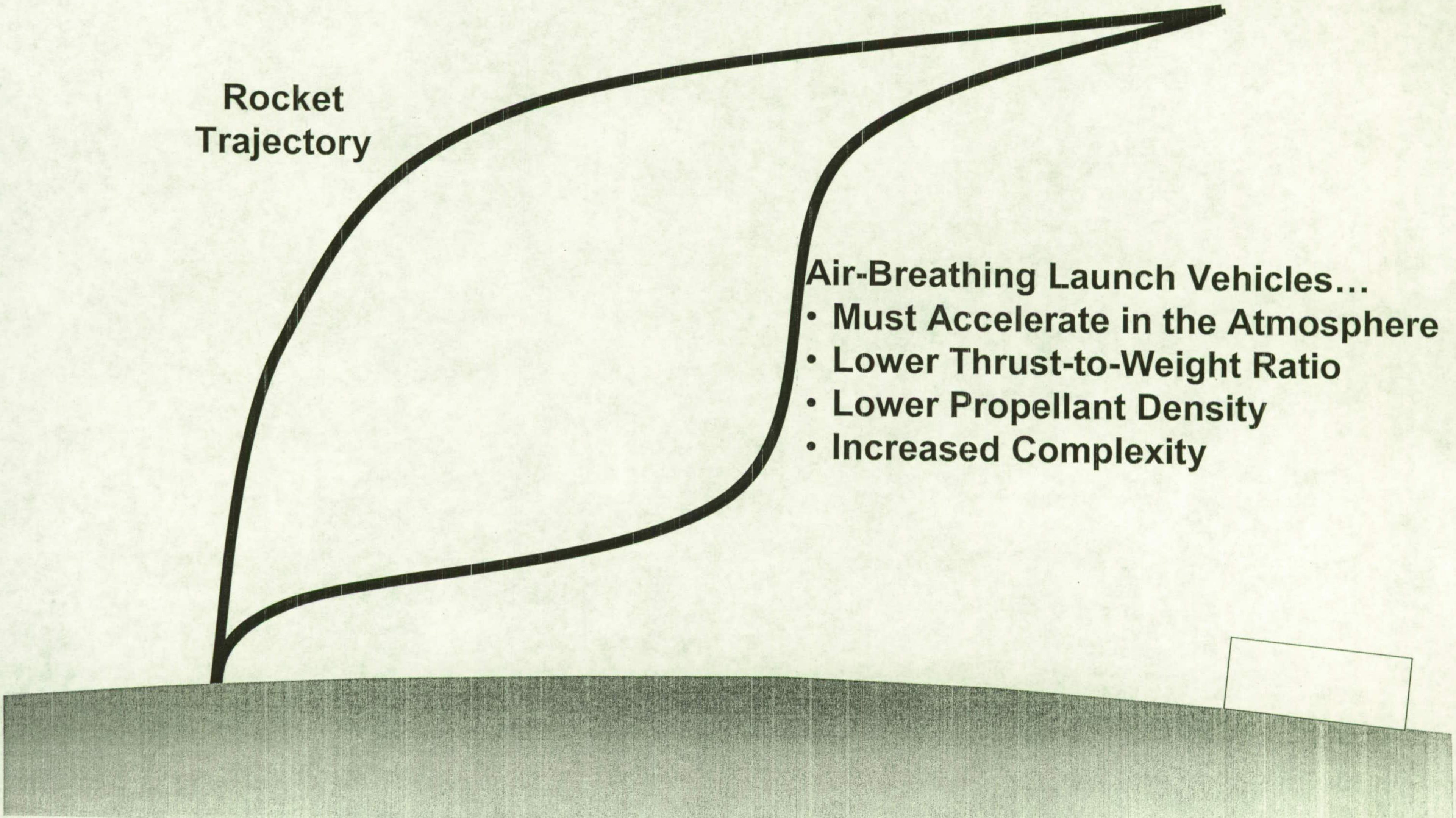
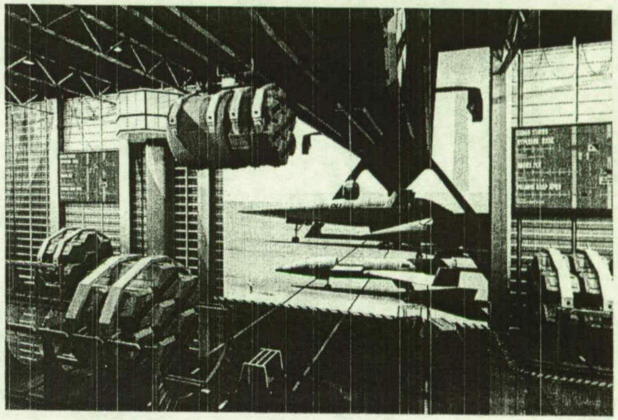
Factors Tending to Mitigate High Air-Breathing Efficiency



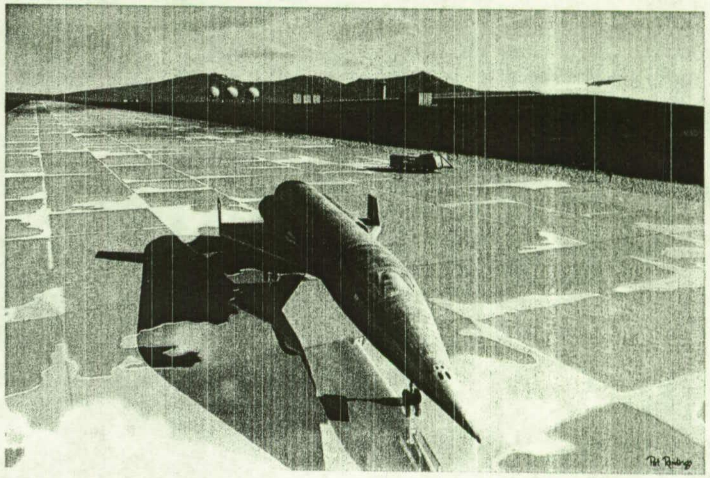
Air-Breathing Launch Vehicles…
- Must Accelerate in the Atmosphere
- Lower Thrust-to-Weight Ratio
- Lower Propellant Density
- Increased Complexity

Advanced Launch Systems

- A 100-fold improvement in safety achieved using systems capable of $100's per pound



- Reliability improvements of 10-fold through performance margins that translate to robust design

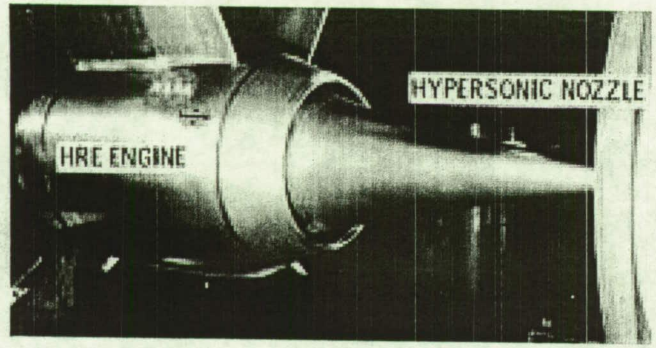


- Approaches could include combined cycle propulsion

Rocket-Based Combined-Cycle Engine

RBCC engines combine the desirable features of the rocket and ramjet cycles in a single, highly-integrated propulsion system

Ramjet

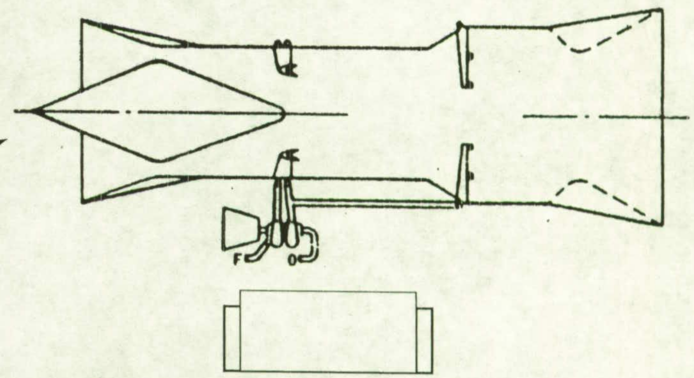


- High efficiency at supersonic speed
- Cannot generate static thrust
- Low thrust-to-weight ratio
- Requires atmospheric oxygen
- Uncertain hypersonic performance

Rocket

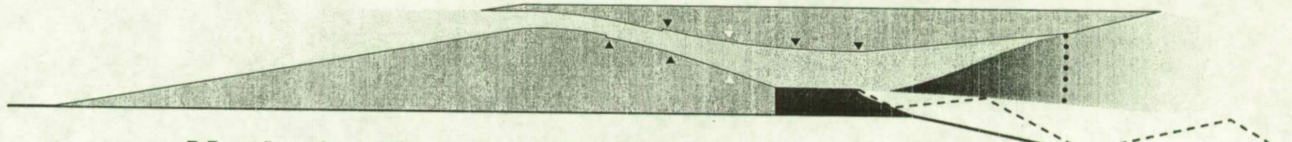
- Thrust at any speed
- Light weight
- Low efficiency

Rocket-Based Combined-Cycle
(Escher, Circa 1966)

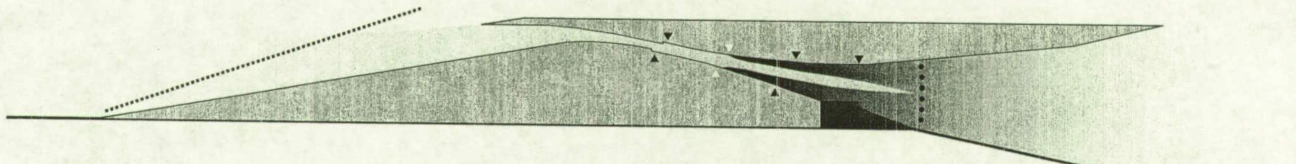


- High thrust at lift-off
- High overall efficiency
- Operates from lift-off to orbit

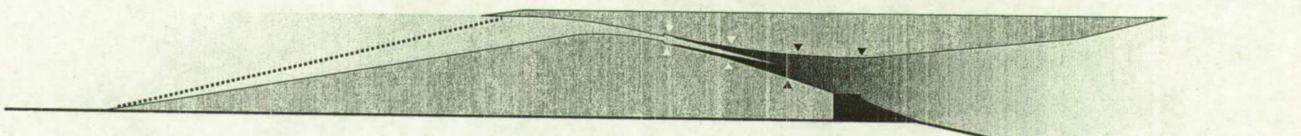
RBCC Operating Modes



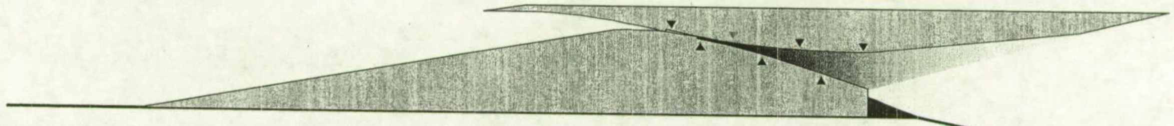
Mode 1 – Rocket / Ramjet ($0 < M_0 < 2.5$)



Mode 2 – Ramjet ($2.5 < M_0 < 5.5$)

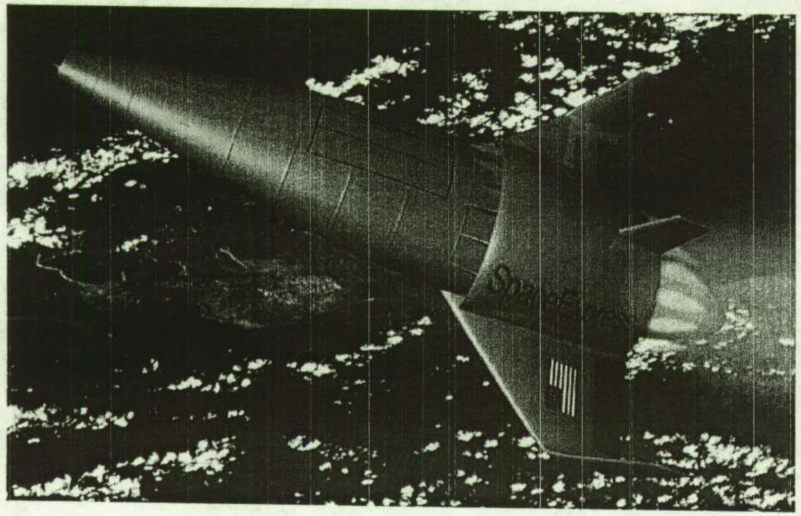


Mode 3 –SCRamjet ($5.5 < M_0 < 11$)

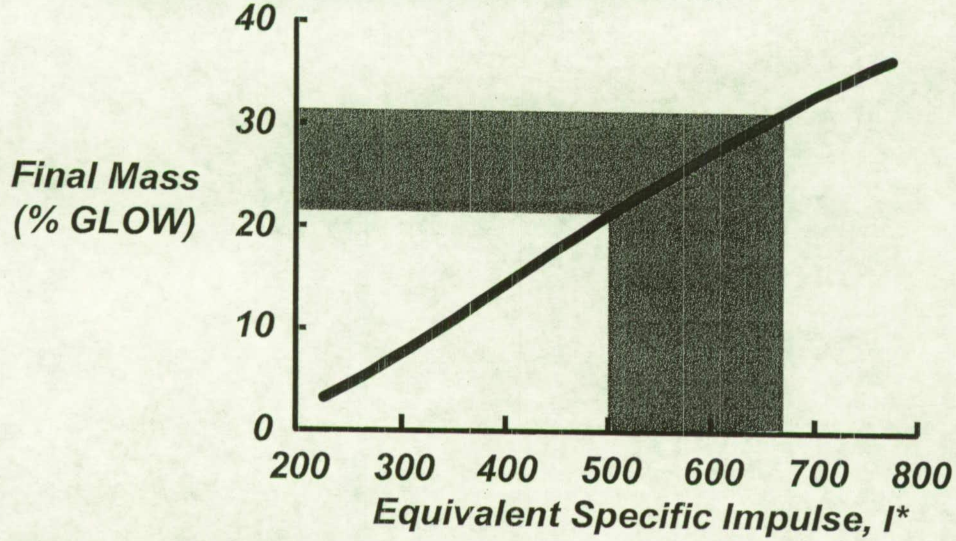


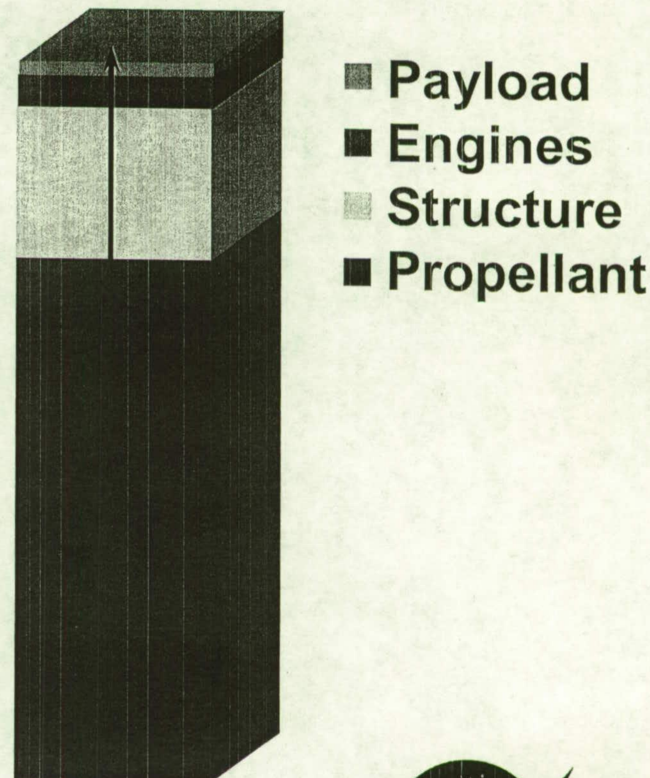
Mode 4 – Rocket ($M_0 > 11$)

Potential for Reusability



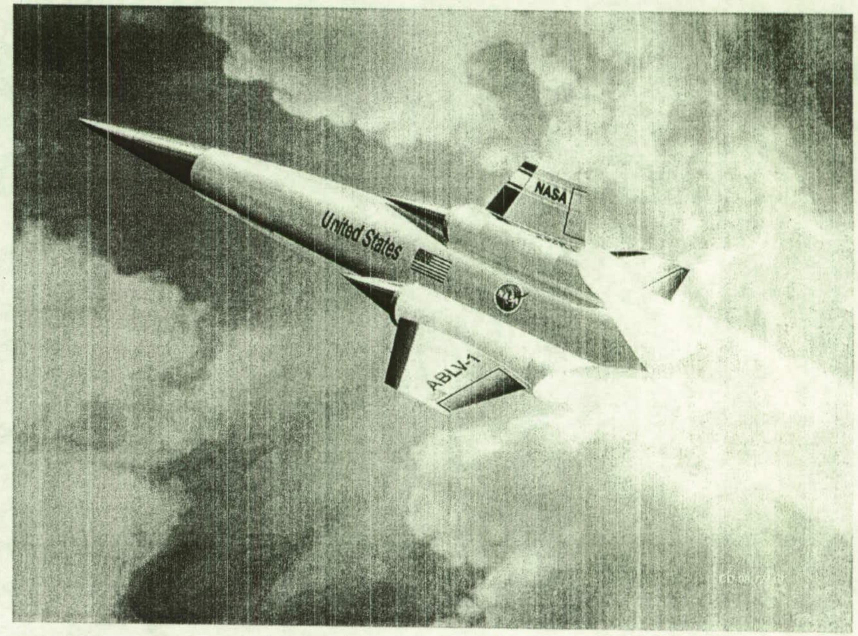
RBCC propulsion provides the potential for reusable SSTO by reducing the fraction of propellant required





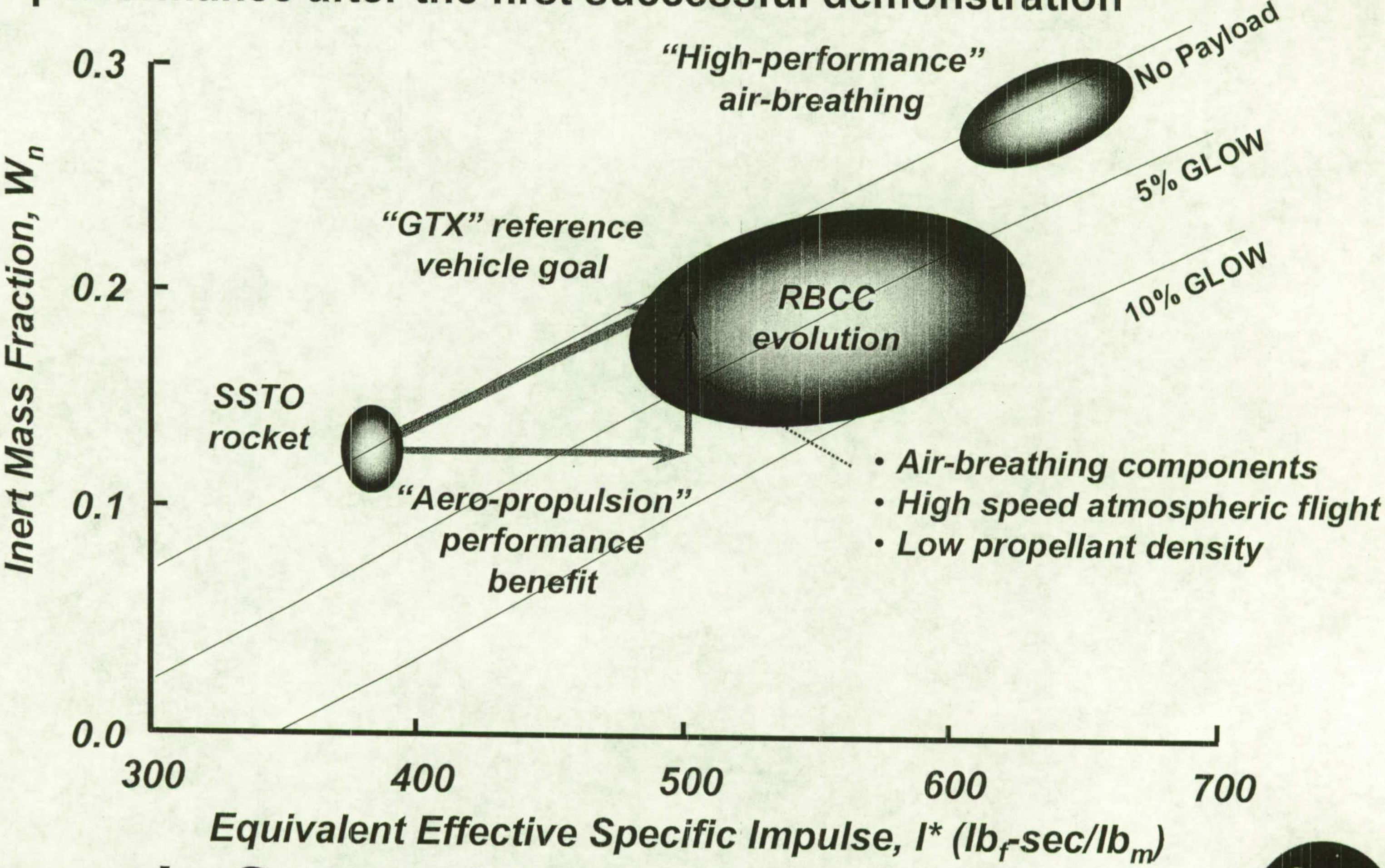
The "GTX" Program

- The "GTX" program was designed to determine if RBCC propulsion can enable reusable SSTO vehicles
- The program was based on maturation of a specific 300 pound payload "reference vehicle"
- Experiments and analyses were conducted to mature the required technologies, and validate component weight and performance estimates



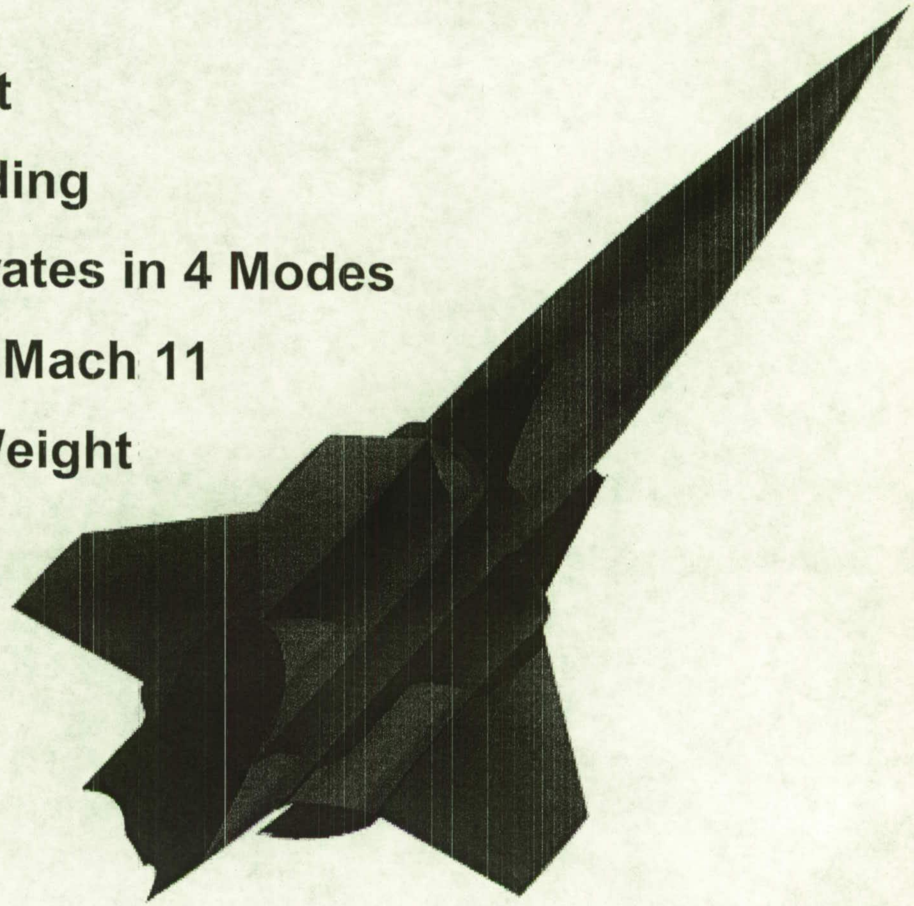
GTX Performance Goal

RBCC-Powered SSTO Launch Vehicles can evolve to higher levels of performance after the first successful demonstration

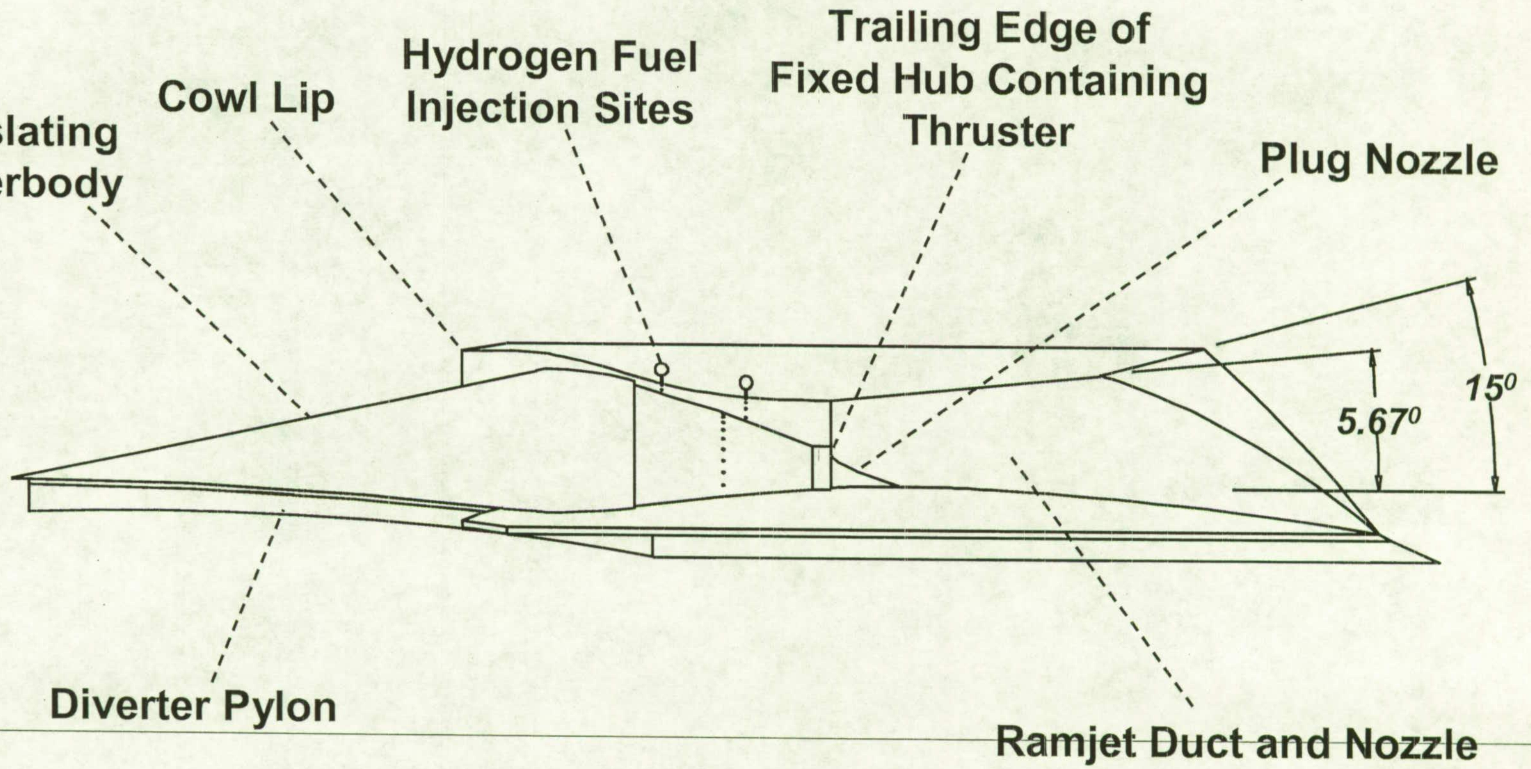


GTX Reference Vehicle Description

- Reusable, Single-Stage-to-Orbit
- Vertical Lift-Off/Horizontal Landing
- RBCC Propulsion System Operates in 4 Modes
- 500 sec Minimum I* at Max A/B Mach 11
- 238,000 pound Gross Lift-Off Weight
- LOX/LH2 Propellants
- 300 pound Payload



Cut-Away View of Propulsion System



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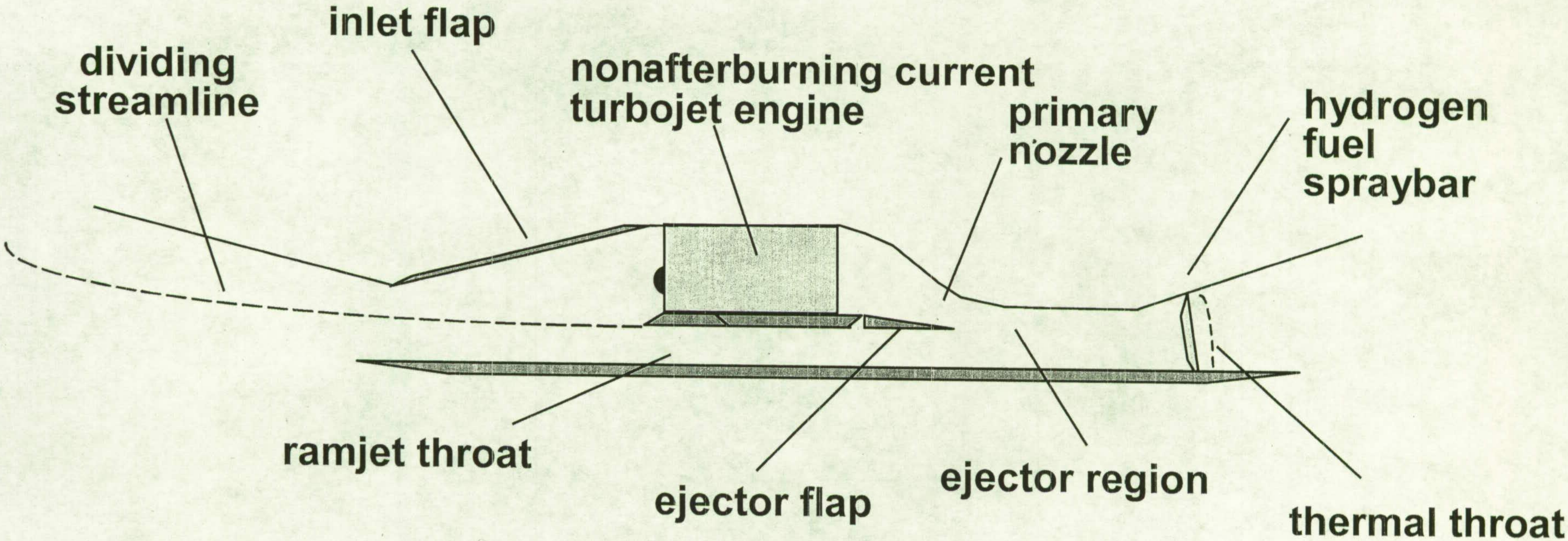
GTX Accomplishments/Key Results

- System approach must be taken due to the highly integrated nature of airbreathing launch vehicles
- Structurally efficient, axisymmetric configuration with limited pre-compression can still achieve an I* greater than 500 seconds
- Limited component performance data was obtained for all 4 propulsion modes in a number of experimental rigs.
- Extensive use of CFD validated and extrapolated experimental results, and guided propulsion system design
- Assuming availability of cooled composite flowpath materials, closure at 690k lbs was shown for the small-payload reference vehicle

Turbine-Based Combined Cycle Concept



Turbine-Based Combined Cycle

Single-Stage to Orbit

Turbine accelerator integrated with dual-mode scramjet in combined flowpath

Technology Challenges

- Turbine accelerator
- Shared inlet
- Dual fuel (HC and H_2)
- Transition mode
- Shared mixer ejector and nozzle
- Thermal management
- Propulsion/airframe integration

Two-Stage to Orbit

First Stage: Turbine accelerator with afterburner or ramjet

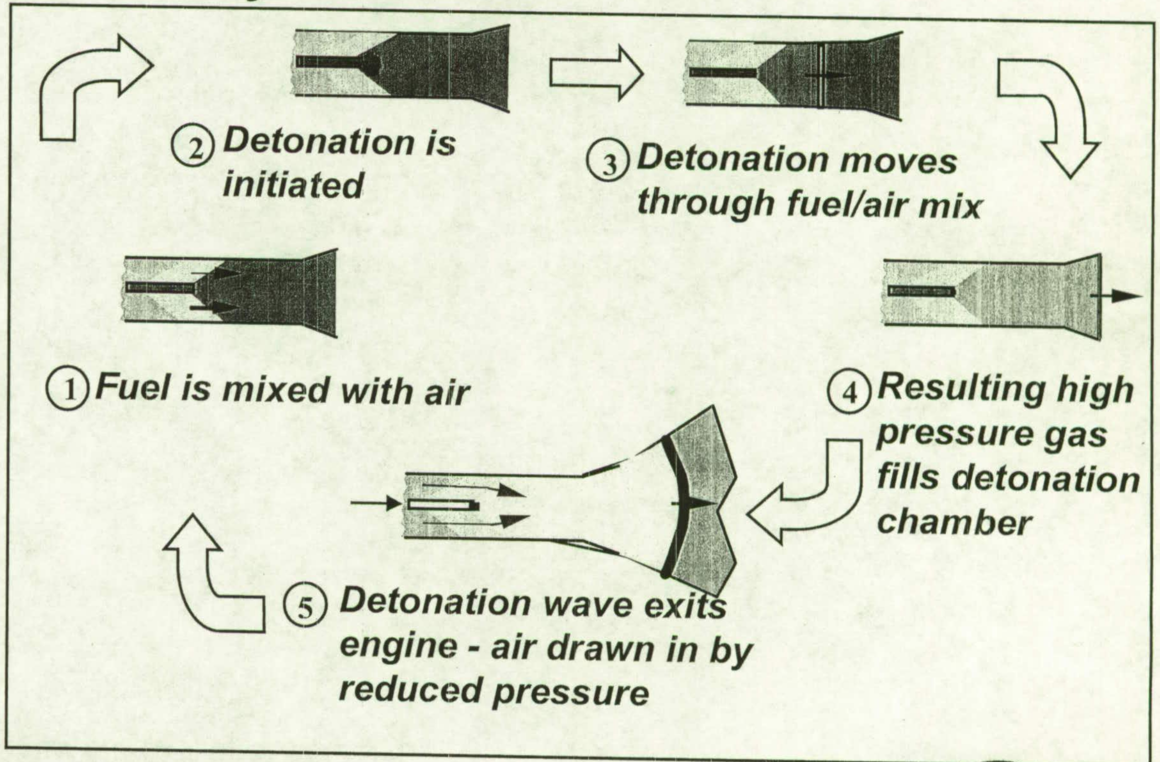
Second Stage: Airbreathing RBCC and/or rockets

Technology Challenges

- Turbine accelerator
- Inlet performance
- Staging separation
- Thermal management
- Propulsion/airframe integration

Pulse Detonation Engine Wave Cycle

- Potential of high specific impulse from a relatively simple mechanism
  - Attractive for the low speed accelerator in a combined cycle
- NASA has studied the feasibility of using PDEs in hybrid-cycle and combined-cycle launch systems.



Conclusions

- NASA has established very challenging goals for reducing launch costs
  - Innovative research programs are in place to help reach these goals.
- Airbreathing concepts offer much promise for lowering launch costs.
- Significant progress has been made in theoretical and experimental studies.